

PRESSURE SENSOR, TRANSMITTER, AND TIRE CONDITION MONITORING APPARATUS

BACKGROUND OF THE INVENTION

5 The present invention relates to a pressure sensor, a transmitter that has the pressure sensor, and a tire condition monitoring apparatus that has the transmitter.

 For example, Japanese Laid-Open Patent Publication No. 8-94468 discloses a structure of a pressure sensor unit, in which a pressure sensor is adhered to a lead terminal that also functions as a shielding member. The pressure sensor is three-dimensionally covered by the
10 lead terminal. This structure prevents the pressure sensor from being affected by outside electromagnetic fields and thus allows the pressure sensor to accurately measure a pressure.

 However, the pressure sensor is three-dimensionally covered with the lead terminal, which also functions as a shielding member. This increases the size of the pressure sensor unit.

 In other words, the structure of the publication cannot reduce a size of a pressure sensor unit that
15 includes a shielding member.

SUMMARY OF THE INVENTION

Accordingly, it is an objective of the present invention to provide a compact pressure sensor that accurately measures a pressure. The present invention also relates to a transmitter having such a pressure sensor and a tire condition monitoring apparatus having such a transmitter.

To achieve the foregoing and other objectives and in accordance with the purpose of the present invention, a pressure sensor having a diaphragm and metallic material is provided. The diaphragm is exposed to gas. The metallic material covers the diaphragm. A predetermined voltage can be applied to the metallic material.

The present invention also provides a transmitter having a pressure sensor that has a diaphragm exposed to gas. The transmitter transmits pressure data detected by the pressure sensor. The transmitter includes a power supply circuit, metallic material, and a connecting member. The power supply circuit supplies electricity to the transmitter. The metallic material covers the diaphragm. The connecting member connects the power supply circuit with the metallic material such that the potential of the metallic material is the same as the potential of the power supply circuit.

Further, the present invention provides a tire condition monitoring apparatus having a pressure sensor that measures air pressure in a tire of a vehicle, a transmitter that transmits pressure data measured by the pressure sensor, and a receiver that receives and processes data transmitted by the transmitter. The pressure sensor includes a diaphragm and metallic material. The diaphragm is exposed to air in the tire. The metallic material covers the diaphragm. The

transmitter includes a power supply circuit and a connecting member. The power supply circuit supplies electricity for activating the transmitter. The connecting member connects the power supply circuit with the metallic material such that the potential of the metallic material is the same as the potential of the power supply circuit.

- 5 Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

5 **Fig. 1** is a block diagram showing a tire condition monitoring apparatus according to one embodiment of the present invention;

Fig. 2 is a diagrammatic view showing the structure of one of the transmitters shown in **Fig. 1**;

Fig. 3 is a block diagram showing one of the transmitters shown in **Fig. 1**;

10 **Fig. 4** is a schematic cross-sectional view showing the pressure sensor shown in **Fig. 3**;

Fig. 5 is a partially cross-sectional view showing the transmitter shown in **Fig. 3**;

Fig. 6 is a schematic cross-sectional view showing a pressure sensor according to another embodiment; and

Fig. 7 is a cross-sectional view showing a casing for accommodating a transmitter
15 according to another embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A pressure sensor, transmitters, and a tire condition monitoring apparatus according to the present invention will now be described with reference to the drawings.

As shown in **Fig. 1**, the tire condition monitoring apparatus 1 includes four transmitters 30 and a receiver 40. Each transmitter 30 is located in one of the tires 20 of a vehicle 10. The receiver 40 is located on a body frame 11 of the vehicle 10.

Each transmitter 30 is located in the corresponding tire 20 and is fixed, for example, to a wheel 21 of the tire 20. Each transmitter 30 measures the condition of the corresponding tire 20, that is, the pressure of the tire 20. The transmitter 30 then wirelessly transmits data containing air pressure data.

The receiver 40 is located at a predetermined position on the body frame 11 and is activated by electricity of a battery (not shown) of the vehicle 10. The receiver 40 includes a single reception antenna 41. The reception antenna 41 is connected to the receiver 40 with a cable 42. The receiver 40 receives data transmitted by the transmitters 30 through the reception antenna 41.

A display 50 is located in the view of the driver of the vehicle 10, for example, in the passenger compartment. The display 50 is connected to the receiver 40 with a cable 43.

As shown in **Fig. 2**, each transmitter 30 is accommodated in a casing 70, that is located below a valve stem 60. Air is injected into the tire 20 through the valve stem 60. The casing 70 is substantially formed into a rectangular box. The casing 70 accommodates a substantially rectangular substrate 80. Electronic elements such as transmission controller 31, a pressure

sensor 32, a transmission circuit 33, a transmission antenna 34, and a battery 35 are mounted on the substrate 80. The substrate 80 is fixed to bosses 71 that are integrally formed with the casing 70. The casing 70 has a through hole (not shown) to permit the pressure sensor 32 to measure the air pressure in the tire 20. The casing 70 has an opening 72, which is closed with a lid (not shown) for protecting the electronic elements.

As shown in Fig. 3, each transmitter 30 includes a transmission controller 31, which is a microcomputer. The transmission controller 31 includes, for example, a central processing unit (CPU), a read only memory (ROM), and a random access memory (RAM). A unique ID code is registered in an internal memory, for example, the ROM, of the transmission controller 31. The ID code is used to distinguish the associated transmitter 30 from the other three transmitters 30.

The pressure sensor 32 measures the air pressure in the interior of the associated tire 20 and provides the transmission controller 31 with pressure data, which is obtained from the measurement. The transmission controller 31 sends data containing the air pressure data and the registered ID code to a transmission circuit 33. The transmission circuit 33 encodes and modulates the data sent from the transmission controller 31. The transmission circuit 33 then wirelessly sends the data through a transmission antenna 34. The transmitter 30 is provided with a battery 35. The transmitter 30 is driven by electricity of the battery 35.

As shown in Fig. 4, the pressure sensor 32 is made of ceramic, and has an upper base 100 and a lower base 200. A metallic material film 101 is formed on the outer surface of the upper base 100. A frustoconical recess 102 is formed in a central portion of the upper base 100. As a result, a diaphragm 103 is formed in an central upper portion of the upper base 100. A first inner

electrode **104** is formed on the lower surface of the diaphragm **103**.

A second inner electrode **201** is formed in a center of the upper surface of the lower base **200**. The metallic material film **101**, the first inner electrode **104**, and the second inner electrode **201** are formed by aluminum deposition. The upper base **100** and the lower base **200** are
5 hermetically attached to each other such that the first inner electrode **104** and the second inner electrode **201** face each other. As a result, a hermetic space **105** is defined between the first inner electrode **104** and the second inner electrode **201**. The hermetic space **105** is filled with gas having a predetermined pressure.

The metallic material film **101**, which covers the diaphragm **103**, is exposed to the air
10 inside the tire **20** through the through hole (not shown) formed in the casing **70**. In other words, the metallic material film **101** is exposed to air, which is a measured gas. Therefore, when the air pressure in the tire **20** changes, the difference between the air pressure in the tire **20** and the pressure of the gas filling the hermetic space **105** is changed. Accordingly, the diaphragm **103** is flexed. Then, the distance between the first inner electrode **104** and the second inner electrode
15 **201**, which changes a capacitance between the first inner electrode **104** and the second inner electrode **201**, accordingly. Therefore, the air pressure in the tire **20** is measured based on the capacitance between the first inner electrode **104** and the second inner electrode **201**. That is, the pressure sensor **32** is a capacitance type pressure sensor.

As shown in Fig. 5, the metallic material film **101** on the upper base **100** is connected to
20 the battery **35** with a lead wire **300** and traces of the wiring pattern on the substrate **80**. The lead wire **300** and the traces function as connecting means. Specifically, the metallic material film

101 is connected to a power supply potential Vdd (+3V) or a ground potential GND (0V) of the battery **35**. As a result, the metallic material film **101** on the upper base **100** is maintained to the same potential as the power supply potential Vdd (+3V) or the ground potential GND (0V) of the battery **35**. The ground potential GND (0V) of the battery **35** is connected to a ground potential GND of the transmission circuit **33**. The battery **35** and the transmission circuit **33** function as a power supply circuit that supplies electricity to the transmitter **30**.

This embodiment has the following advantages.

(1) The metallic material film **101** is formed on the outer surface of the upper base **100** to cover the diaphragm **103**. The metallic material film **101** on the upper base **100** is connected to the power supply potential Vdd (+3V) or the ground potential GND (0V) of the battery **35** with the lead wire **300** and the traces on the substrate **80**. Accordingly, the metallic material film **101** on the upper base **100** is maintained to the same potential as the potential of the battery **35**. As a result, the first inner electrode **104** and the second inner electrode **201** of the pressure sensor **32** are shielded by the metallic material film **101**. This structure prevents the pressure sensor **32** from being affected by outside electromagnetic fields and thus allows the pressure sensor **32** to accurately measure the air pressure in the tire **20**. Unlike the structure disclosed in Japanese Laid-Open Patent Publication No. 8-94468, where the pressure sensor is three-dimensionally covered with a lead terminal that also functions as a shielding member, the metallic material film **101** on the upper base **100** is connected to the ground potential GND on the substrate **80** with the lead wire **300**. Therefore, the size of the pressure sensor **32** is reduced.

(2) Since the size of the pressure sensor **32** is reduced, the size of the transmitter **30** is

reduced. Therefore, when attaching the tire **20** to the wheel **21**, the bead of the tire **20** is prevented from contacting the casing **70**, which accommodates the transmitter **30**. Therefore, when attaching the tire **20**, the casing **70** and the transmitter **30** are not damaged.

(3) The pressure sensor **32** is scarcely affected by outside electromagnetic fields. This permits the pressure sensor **32** to accurately measure even small changes in the air pressure in the tire **20**. Therefore, the transmitter **30** wirelessly transmits accurate air pressure data to the receiver **40**.

(4) The receiver **40** receives data through the reception antenna **41** and, based on the received data, causes the display **50** to display air pressure data. This informs a driver of the vehicle **10** of the accurate air pressure data. In other words, the present invention provides the tire condition monitoring apparatus 1, which accurately measures the air pressure in the tire **20**.

It should be apparent to those skilled in the art that the present invention may be embodied in many other specific forms without departing from the spirit or scope of the invention. Particularly, it should be understood that the invention may be embodied in the following forms.

The metallic material film **101** on the upper base **100** may be directly connected to the power supply potential Vdd (+3V) or the ground potential GND (0V) of the battery **35** with the lead wire **300**, without using the traces on the substrate **80**.

As shown in Fig. 6, the metallic material film **101** on the upper base **100** may be connected to the power supply potential Vdd (+3V) or the ground potential GND (0V) of the battery **35** with the traces on the substrate **80** and a tungsten plated through hole **400**.

As shown in **Fig. 7**, a conductor **500** having bent ends may be provided on a lid **73** of the casing **70**. The metallic material film **101** on the upper base **100** may be connected to the battery **35** (for example, a positive terminal) with the conductor **500** when the opening **72** is closed with the lid **73**. In this case, the shielding effect is obtained only by closing the opening **72** of the casing **70** with the lid **73** with the conductor **500**. Compared to conventional assembly procedure, only a step for attaching the conductor **500** to the lid **73** is added. In other words, no complicated step is added to the procedure for obtaining the shielding effect. Thus, with the structure of the lid **73** having the conductor **500**, the transmitter **30** is easily assembled with the casing **70**.

In the illustrated embodiment, the metallic material film **101** is formed on the entire upper surface of the upper base **100**. However, the metallic material film **101** may be formed on a part of the upper surface of the upper base **100** to cover the diaphragm **103**. That is, the metallic material film **101** may be formed only on a center portion of the upper surface of the upper base **100**.

Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.